

Chapter 16

Feedstocks, fermentation and distillation for production of heavy and light rums

J.E. Murtagh

Murtagh & Associates, Winchester, Virginia, USA

Introduction

The US Bureau of Alcohol, Tobacco and Firearms regulations (1982) define rum as: 'an alcoholic distillate from the fermented juice of sugar cane, sugarcane syrup, sugarcane molasses or other sugarcane by-products, produced at less than 190° proof (95° GL), in such a manner that the distillate possesses the taste, aroma and characteristics generally attributed to rum, and bottled at not less than 80° proof (40° GL), and also includes mixtures solely of such distillates'.

It should be noted that unlike the US regulations for whisky, the regulations for rum do not include any requirement that it be aged in oak barrels for a minimum period of time. The US regulations also do not specify any geographic region in which rum may be produced, however the British regulations define rum as: 'a spirit distilled directly from sugarcane products in sugarcane-growing countries'.

The regulations are rather vague of necessity owing to the very wide variety of rums ranging from the light, nearly neutral, continuous still products to the heavily flavored, dark, navy-type pot still products. The diversity of rum types and their production methods makes comprehensive coverage of the industry almost impossible for a

publication such as this. Thus, readers should consult the references for additional information. What are now considered the classic studies on rum production were published by Rafael Arroyo of Puerto Rico in the 1940s (see reference list). That was at a time when the island's rum industry increased production very significantly in order to meet the demand arising from a wartime shortage of whisky and grain spirits. Other more recent studies and helpful reviews of the rum industry have been published by Clutton (1974), Ianson (1971), Kampen (1975), Lehtonen and Suomalainen, (1977) and Paturau (1969).

Feedstocks: fresh sugarcane juice or diluted molasses

Cane juice

Using cane juice for rum production has both advantages and disadvantages. The main advantage is that no additional processing is required. The cane is simply crushed and the juice fed directly into the fermenters. Another advantage is that cane juice does not have a high content of dissolved salts and therefore does not

cause as much scaling and blocking of distillation columns as may occur using molasses.

One of the main disadvantages of using cane juice is that it normally contains only about 12-16% w/w sugar, so that the alcohol content of the fermented material is limited to about 6-8% v/v as compared to 10-13% v/v obtainable from molasses. Another significant disadvantage is that cane juice cannot be stored in bulk for any considerable length of time. Heavy contamination with bacteria and yeasts causes it to start to ferment spontaneously and very rapidly. This means that the distillery must be located in close proximity to the cane mill. It also means that the cane juice is only available during the cane harvesting season, which generally does not exceed six months per year. Thus, some rum distilleries may use cane juice during the harvest season and molasses for the remainder of the year. Cane juice may also have cost disadvantages in that it is a primary, or at least an intermediate product in the production of sugar. In contrast, molasses is generally a by-product, considered to be of lower value.

Cane juice normally becomes heavily infected with bacteria and yeasts in the crushing process. Pasteurization prior to fermentation is usually infeasible due to the large amount of suspended fiber in the juice, which would tend to block most heat exchangers. Thus the contaminating organisms may significantly reduce alcohol yields from cane juice.

Molasses

The use of molasses as a feedstock for alcohol production has been covered in an earlier chapter in this volume; therefore only a few comments are necessary with specific reference to rum.

The source of the molasses can have a strong influence on the aromatic quality of rum. This has been demonstrated in trials on making rum from beet molasses where it was found that it was not possible to obtain the same characteristic aromas as obtained from cane molasses (Arroyo, 1948b). Arroyo (1941, 1942) reported that fresh

blackstrap molasses with its low viscosity, high total sugars, nitrogen, phosphorus and a low ash and gum content was preferable in the production of rums with desirable odors and tastes.

Fermentation methods

Heavy rum

Just as there are many different types of rum, there are many different methods of fermentation. In the production of heavily flavored rums, cane juice or diluted molasses mash may be allowed to ferment spontaneously using yeasts present naturally in the feedstock. This is relatively inefficient in terms of alcohol production; and the results may vary. However, it is the high level of bacterial contamination in these fermentations that produces many of the desirable congeners such as acids and esters. In some processes, e.g. in Jamaica, the spontaneous fermentation may be assisted by the addition of 'dunder' at the start of fermentation. Dunder is old stillage that has been stored in open tanks to allow development of a strong bacterial flora.

To attempt a more controlled fermentation in production of heavy rums, a pure culture of yeast may be used together with a pure bacterial culture. A specially selected strain of yeast, usually *Saccharomyces cerevisiae*, which is a budding yeast, or possibly other species such as the fission yeast *Schizosaccharomyces pombe*, is propagated from an agar slant. This culture is transferred every 12-24 hrs through a series of Erlenmeyer flasks each holding increasing amounts of sterilized, diluted molasses mash supplemented with malt syrup or other sources of nutrients. When about 20 liters of yeast culture have been produced, it may be used to inoculate about 200 liters of diluted molasses mash in a small plant propagator or 'prefermenter'. The contents of the vessel are aerated, and after about 8-12 hrs of propagation are used to inoculate a larger prefermenter containing about 2,000 liters of mash. This vessel may also be

aerated and fed incrementally with more diluted molasses medium until it contains the equivalent of about 10% of the capacity of the plant fermenters.

It is generally considered desirable to have a minimum of about 50 million yeast cells/ml of medium when the fermentation has been completed. Thus, after allowing for yeast propagation during the filling process, the 10% yeast inoculum should have a cell count of about 200 million cells/ml to achieve this objective.

A pure culture of bacteria such as *Clostridium saccharobutyricum* may be added after 6-12 hrs of the yeast fermentation. Usually the bacterial inoculum amounts to about 2% of the fermenter capacity; and the pH of the fermenting mash is adjusted upwards to about pH 5.5 before addition to give more suitable conditions for the bacterial propagation. The bacteria produce a mixture of acids, predominantly butyric, together with others such as acetic, propionic, and caproic acids. These acids in turn react with the alcohol to produce desirable esters.

Fermentation for light rums

In light rum production, the emphasis is generally on maintaining clean, rapid fermentations to minimize development of undesirable congeners and to maximize fermentation efficiency. Pure cultures of yeast may be propagated as previously described. These may be accompanied by the use of antibiotics such as penicillin or bactericides such as chlorine dioxide, ammonium bifluoride or quaternary ammonium compounds to control bacterial contamination.

Some plants use 'mother yeasting'. In this system a pure yeast culture is propagated in the prefermenter. The pH is lowered to about 3.7 to reduce bacterial growth; and up to 90% of the yeast volume is used to inoculate a fermenter. The prefermenter is refilled with mash to repeat the process several times.

In other plants, the yeast may be recycled from one fermenter to another. This is done by centrifuging the yeast out of the fermented beer prior to distillation and then subjecting it to an

acid washing at pH 2.2-2.5 to kill most of the contaminating bacteria. As an alternative to acid washing, the yeast may be treated with about 15 ppm chlorine dioxide at a pH of about 3.5. The objective of yeast recycling is to save on sugar that would otherwise be needed for yeast growth and to ensure a very high cell count in the fermenter inoculum. This provides a rapid fermentation in which bacteria lack sufficient opportunity to get well established.

Commercial dry yeasts may also be used in light rum fermentations. A large quantity of dry yeast may be added to the molasses mash at the start of fermenter filling. More commonly, in order to save cost a smaller quantity of the dry yeast may be rehydrated and propagated for several hours in a prefermenter before transfer to the fermenter.

Distillation

The method of distillation used has a considerable effect on the nature of the rum product. Heavy rums are usually produced by batch distillation, while light rums are normally produced by continuous distillation.

Batch distillation: heavy rum

Batch distillation may be performed with various types of equipment. The simplest form is a single, simple pot still. Here, the fermented beer is transferred into a copper tank or 'pot', as shown in Figure 1. The pot is heated either by an internal steam coil (calandria) or by a fire of wood or bagasse underneath, usually in a brick enclosure. The pot is fitted with a vapor pipe which leads to a condenser coil immersed in a water tank. As the beer is heated, the alcohol and other volatile congeners are distilled off, condensed and run into a storage tank. Usually the first fraction distilled contains much of the more volatile, pungent 'heads' congeners and is discarded as the 'heads cut'. The process is continued until most of the alcohol has been distilled out of the beer.

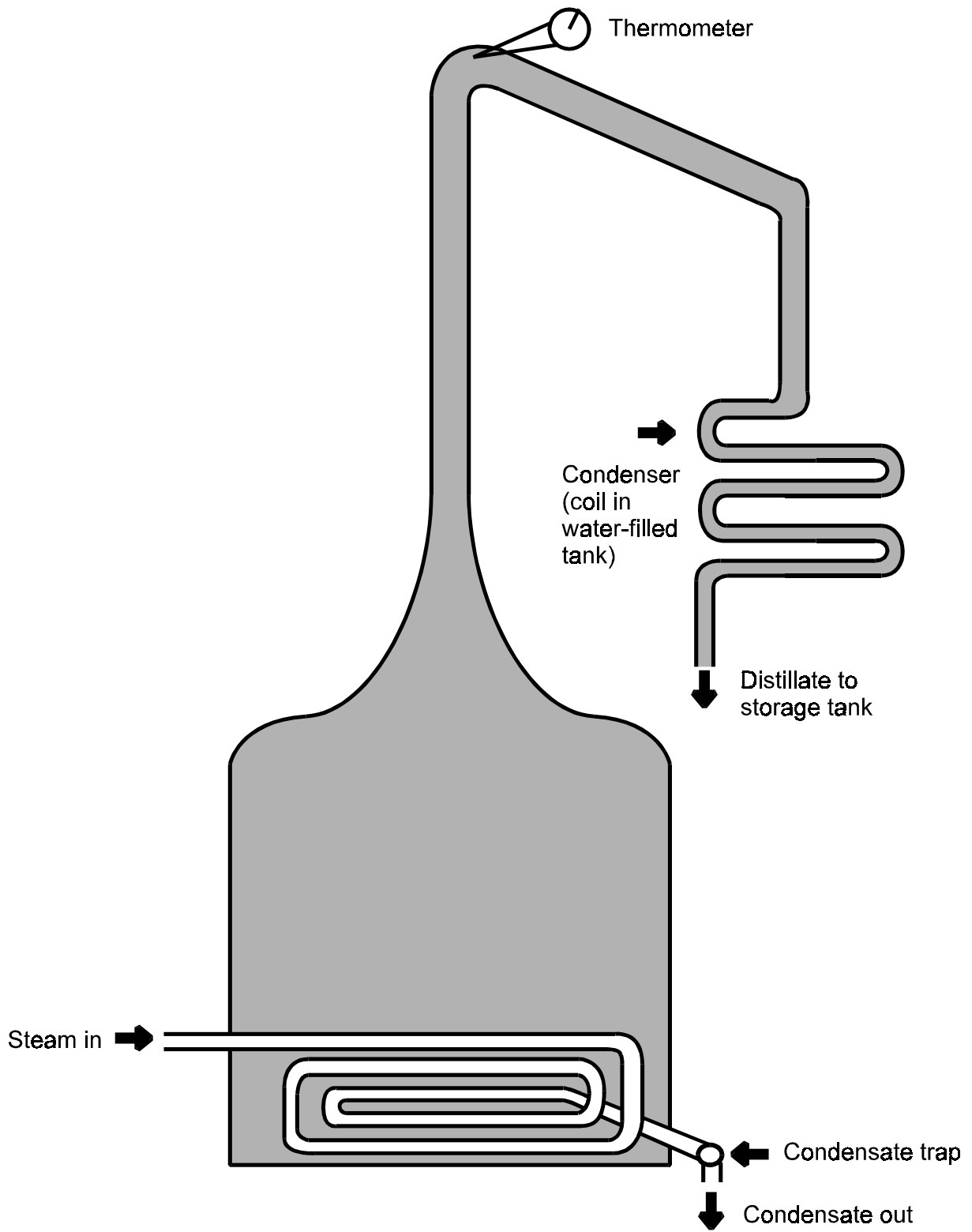


Figure 1. Simple pot still for heavy rum production.

The beer residue, or 'stillage', is emptied out of the pot and the distillate is returned from the storage tank to the pot to be redistilled to increase the proof. A heads cut may again be discarded together with a 'tails cut' taken toward the end of the distillation. The 'center cut', which is the bulk of the distillate, has the more pleasant aromas of fruity esters characteristic of rum. Normally, there are only two pot distillations, but there may be a third if desired.

Two or three pot stills may be interconnected, as shown in Figure 2, to eliminate the need to transfer the distillate back into the first pot for redistillation and to conserve energy. The efficiency of the pot still in separating congeners may be improved considerably by including perhaps five or six bubble cap trays between the pot and the vapor pipe, and a simple condenser above the trays to provide some reflux as shown in Figure 3. This is the design of pot still most frequently used by small, on-farm producers of common tafia and aguardiente rums. It is a simple progression from this pot still to the batch kettle and column still used by larger scale rum producers, as shown in Figure 4.

In some countries crude rum or aguardiente is produced on a small scale by numerous farmers using pot stills. Their product may then be sold to companies that redistill it in a batch system to standardize quality for sale as heavy rum or for blending with neutral or nearly neutral spirits to make light rums.

Continuous distillation: light rum

Continuous distillation is usually confined to the production of light rums. A two column beer still with a Barbet type prestripper, as shown in Figure 5, is normally preferred as it permits removal of heads, volatile sulfur compounds and some other undesirable fractions before the bulk of the alcohol enters the concentrating column. (Operation of this type of beer still is discussed in the chapter on neutral spirit production).

When a lighter or less flavorful rum than can be produced on a simple two column beer still

is required, an extractive distillation column and a rectifier as employed in neutral spirit production can be used (Figure 6).

Combinations of batch and continuous distillation

There are many possible variations and combinations of distillation processes. For example, crude pot still distillates may be put through a simple continuous distillation unit to produce a more acceptable, standardized product. Arroyo has described two techniques for combinations of continuous and batch distillations to produce both heavy and light rums at the same time. In one system Arroyo (1948c) suggested that the beer first be distilled in a single continuous column with only about five concentrating plates. Provision for fusel oil removal allows some control over the fusel content in the distillate, which has a proof of about 70° GL. He then recommended that the distillate be diluted to about 40° GL and be submitted to a batch distillation.

The distillate from the batch column should be collected as five separate fractions based on monitored odor variations and rising distillation temperature. Arroyo found that the first fraction, which distilled between 69 and 72°C at a proof of about 91° GL, represented about 5% of the total distillate volume and consisted of unpleasant aldehydes, organic acids and esters. He recommended this fraction either be discarded or held for subsequent reprocessing to recover some of the ethanol. The second fraction, distilling over a temperature range of 72-77°C at a proof of 93-94° GL, represented about 10% of the total distillate volume and contained ethanol with appreciable amounts of aldehydes and esters. The third fraction, which distilled at a fixed temperature of 78°C and a proof of about 95.5° GL, was the largest in volume at 55-60% of the total and contained mostly ethanol with very small amounts of congeners such as aldehydes, esters and higher alcohols. It also contained the lowest

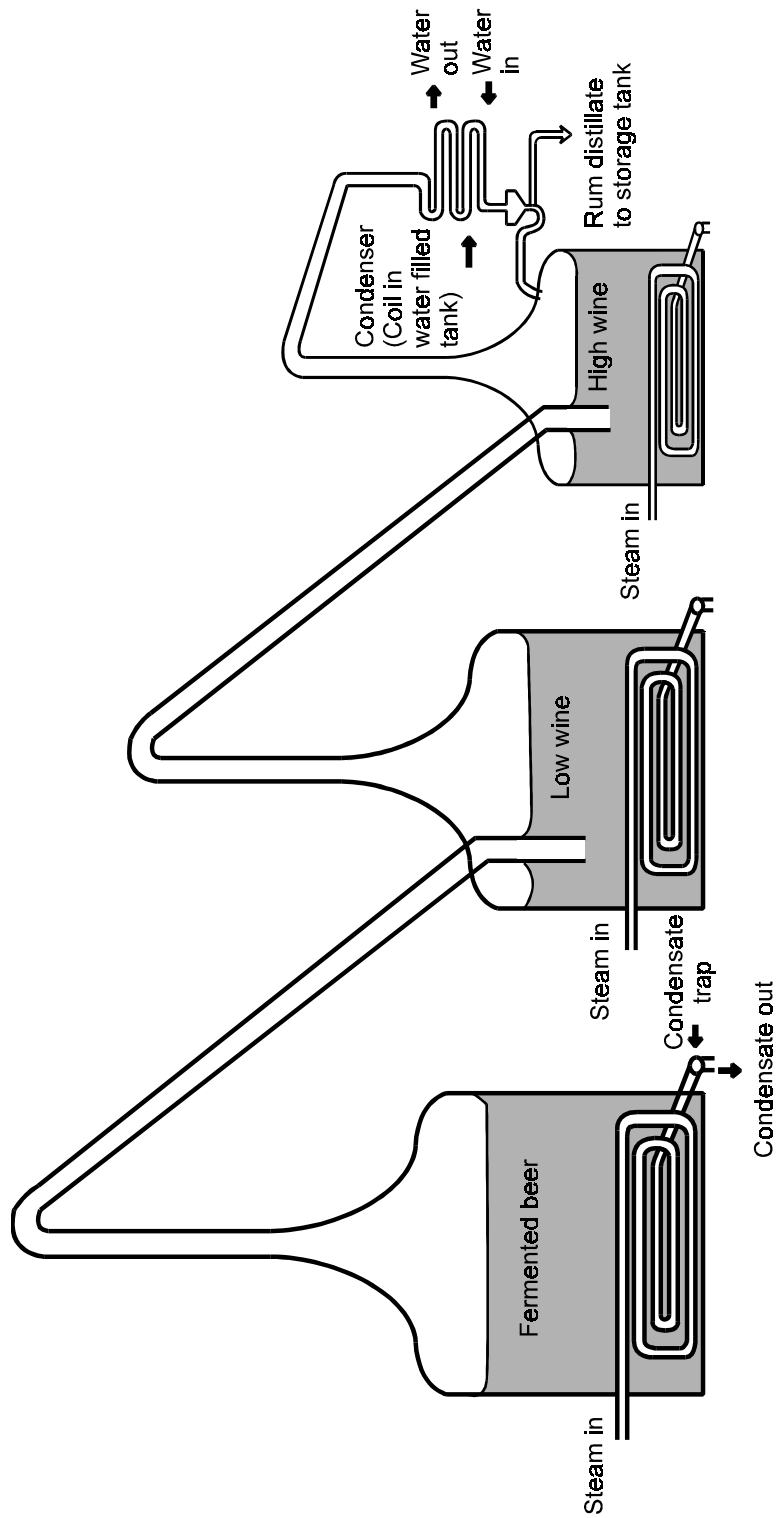


Figure 2. Triple pot still system for heavy rum production.

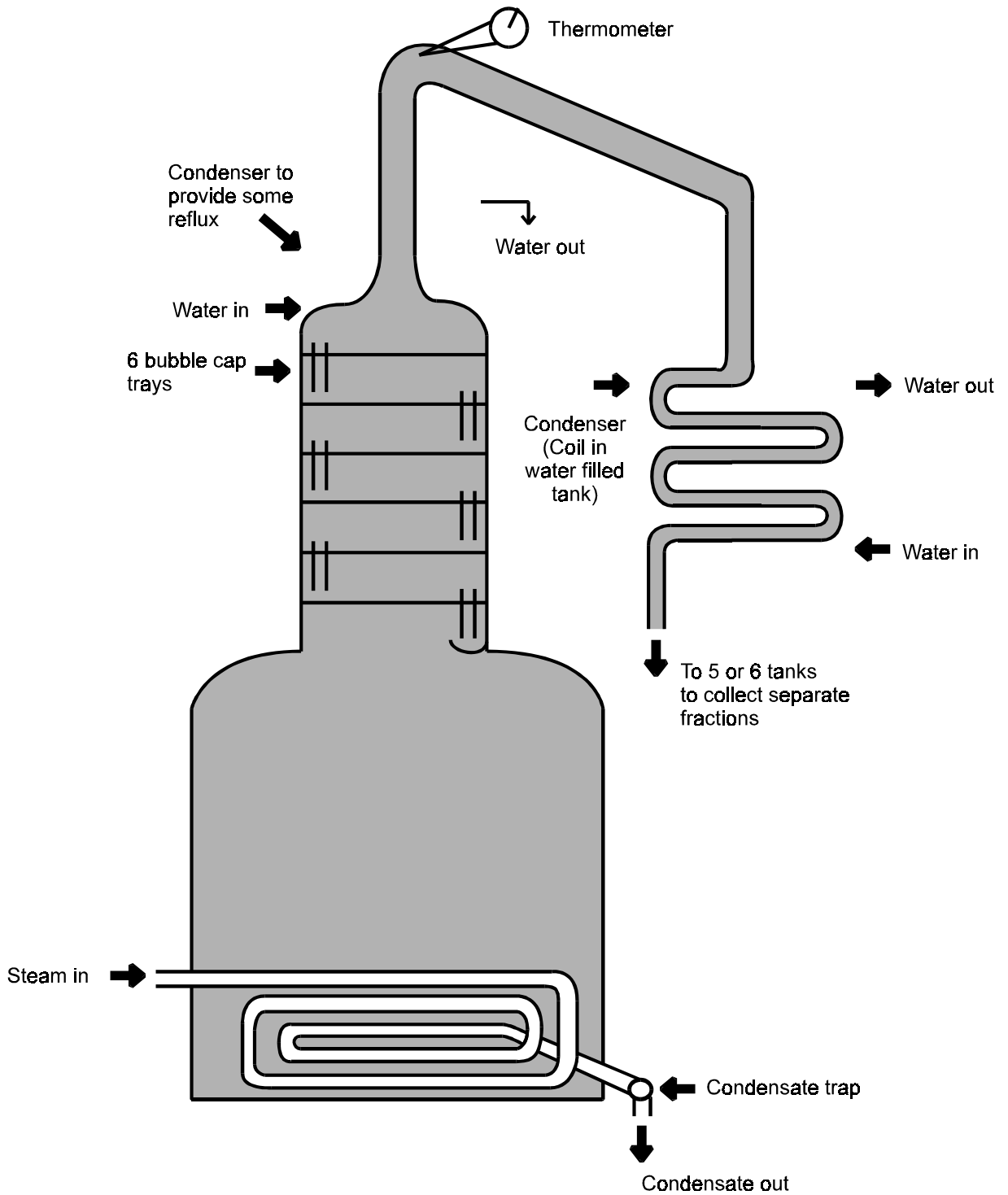


Figure 3. Pot still with bubble cap tray section.

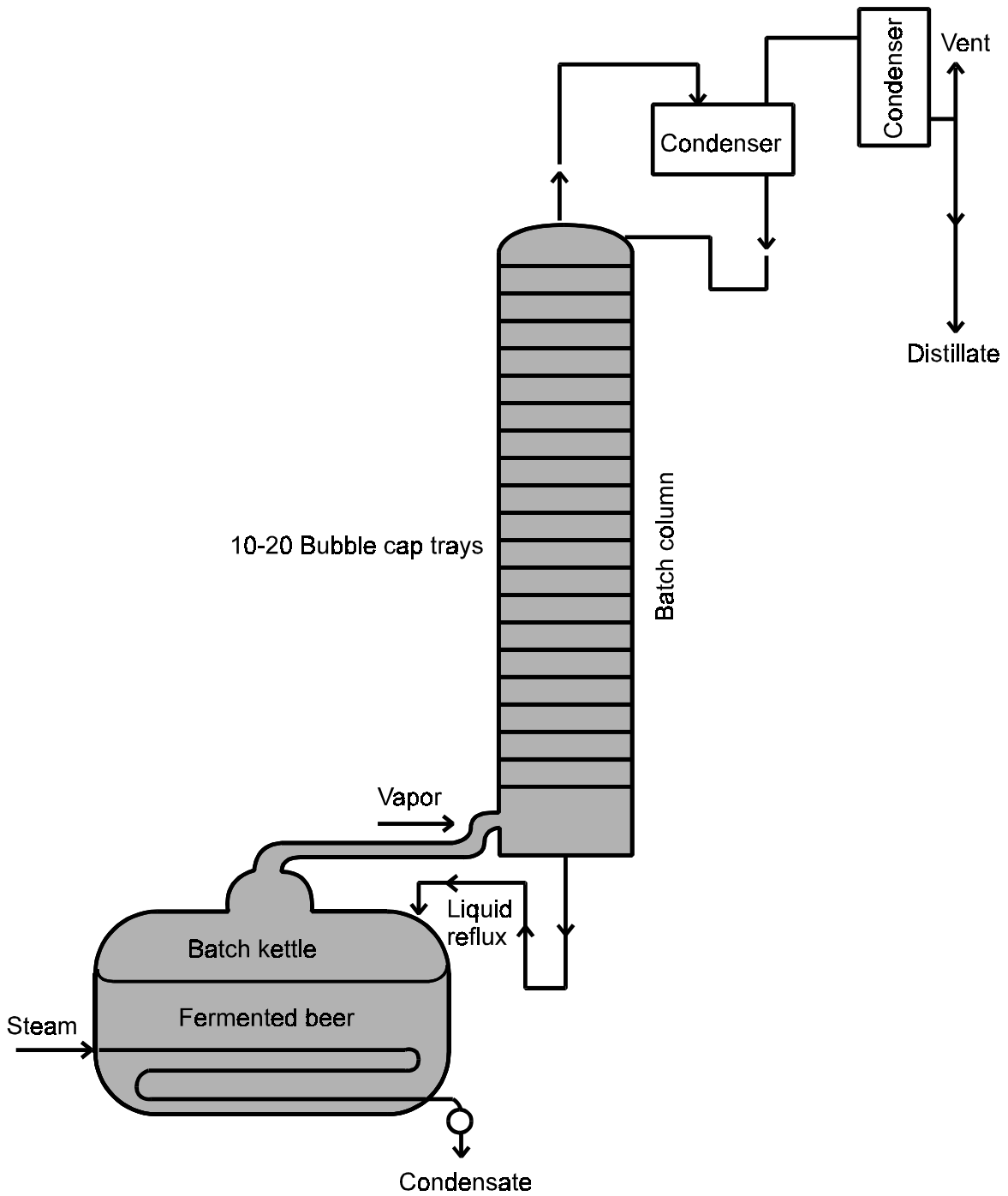


Figure 4. Batch still for rum production.

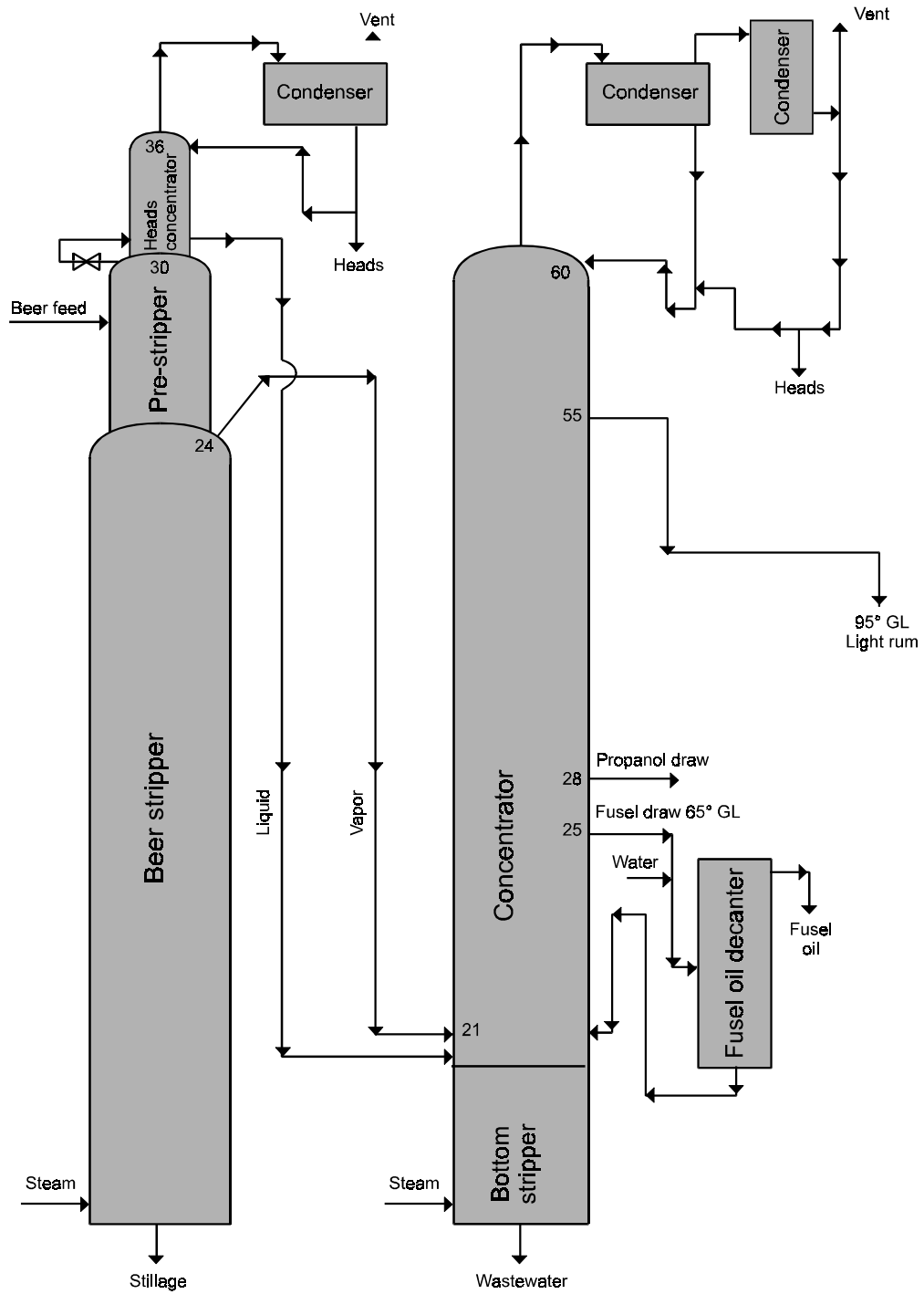


Figure 5. Modified Barbet beerstill for light rum production.

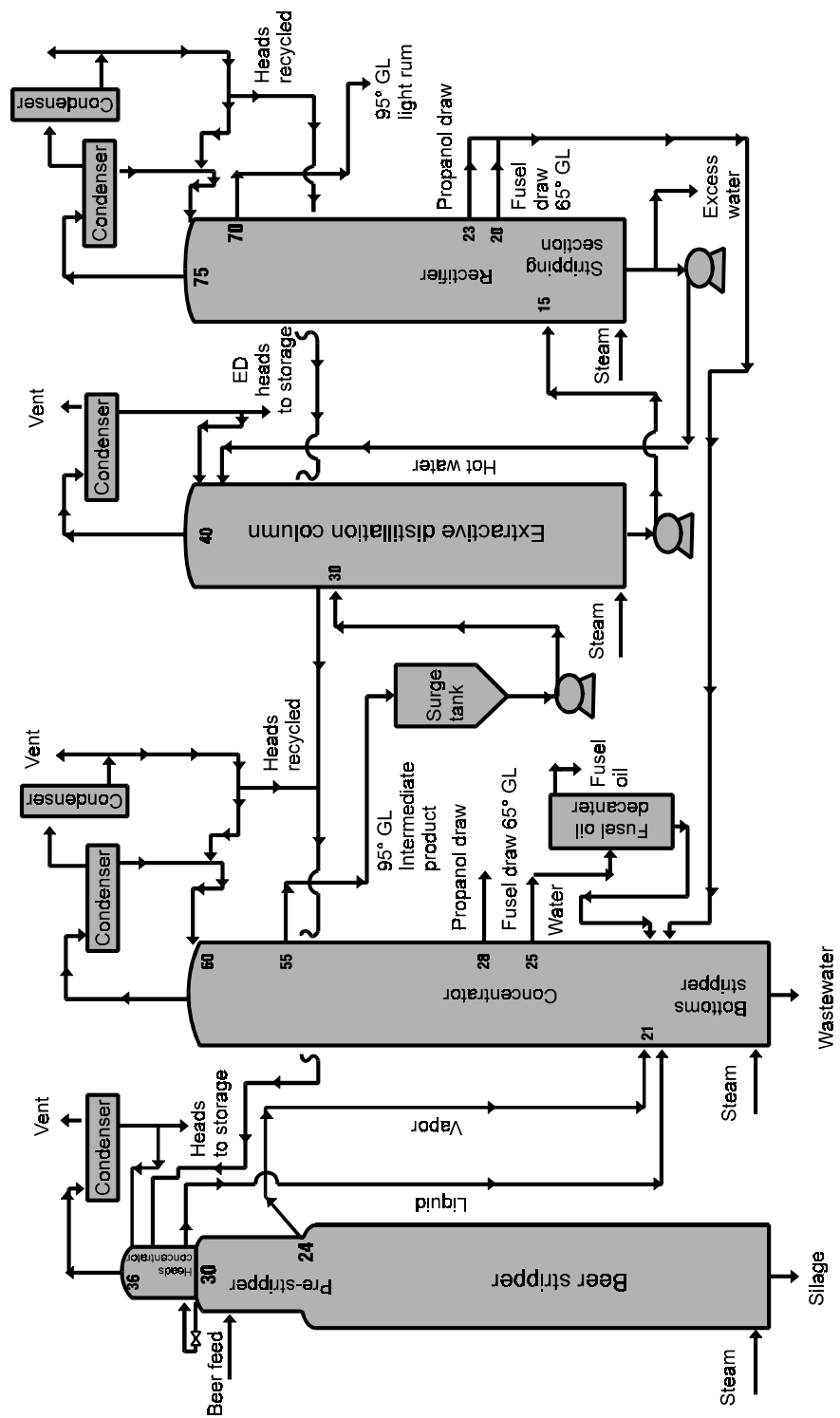


Figure 6. Four column distillation and rectification system for the production of light rum.

concentration of volatile organic acids. The fourth fraction was collected at a distilling temperature range of 78.5-85°C at a proof of about 90° GL. This fraction was characterized by the presence of most of the higher alcohols from the original continuous still distillate together with more esters, aldehydes and acids than in the previous fraction. The fifth and final fraction was collected over a distilling temperature range of 85-90°C and had a much lower proof than the other fractions (25-30° GL). This fraction was opalescent or turbid due to the presence of some of the highest boiling point esters and aldehydes which are more soluble in ethanol than in water.

Arroyo then recommended mixing the last four fractions in various proportions to make both light and heavy rums. He quoted an example of using 25% of the second fraction, 50% of the third fraction, 40% of the fourth fraction and 15% of the fifth fraction to make a light rum while using all the balances to make a heavy rum and avoid wastage.

In another combined process, Arroyo (1949b) suggested that the various congener sidestreams removed in the production of very light rums or neutral spirit by continuous distillation should be mixed, diluted with water and subjected to a fractional distillation almost identical to that used in the previous process. The distillate should be split into a similar set of five fractions with the first discarded, the third mixed with the light rum and the other three fractions used in various proportions for blending heavy rums. Arroyo claimed that these rums matured more rapidly than normally produced heavy rums when aged in oak barrels. As such there was a saving on warehouse space and other costs.

Rum maturation and blending

The normal and most reliable method of maturing rum to make it more suitable for consumption is by aging in oak barrels. Light rums with very low levels of congeners may require very little aging and may be acceptable after just a few weeks in

barrels. In fact, many of the currently popular lighter rums are not aged at all. The heavy rums, however, tend to require much more aging to become palatable and may be held in barrels for five years or longer.

The barrels normally used for rum aging are obtained from the US, where government regulations specify that bourbon whiskey must be aged in new oak barrels thereby creating a large supply of once-used barrels. The bourbon barrels are charred on the inside and are used for aging rum either with the char intact or after its removal, depending on the preference of individual distillery.

Oak wood has a strong influence on the maturation and ultimate flavor of the rum, largely due to the extraction of compounds such as tannins and calcium salts and colorings such as quercitine. The type and quantity of the extracted compounds depend largely on the length of time and temperature of aging, the proof of the rum, the type and former usage of the barrel and the amount of contact surface it offers. New oak barrels, or fresh, once-used bourbon barrels naturally have more extractable compounds than old barrels that have been used many times over several years. Thus, a light rum stored in new or once-used barrels for a year or two may emerge with much of the odor and taste of a bourbon whiskey, as the main characteristics of bourbon are derived from the oak wood. This odor and taste may or may not be desirable. A program should therefore be established to identify individual barrels and code them as to history of usage in order to select particular types or ages of barrels for particular rum products. For example, in countries requiring that rum be aged in wooden barrels for a minimum period of time (which may be 1-3 years), light rums should be aged in the oldest available barrels as these will contribute the least amount of flavor. Even then, it may be necessary to treat the aged product with activated charcoal to reduce the color and flavor before bottling.

The main reactions that take place during aging to make rums more palatable are esterification, condensation and oxidation. The formation of

esters involves a reaction between acids and the ethanol or other alcohols in the rum, and can take a considerable amount of time. The presence of esters gives the rum a generally desirable fruity aroma. In the condensations, molecules such as aldehydes and alcohols may combine to form acetals. In oxidations that occur with air passing through the pores in the wood, ethanol may be oxidized to acetaldehyde, which in turn may be oxidized to acetic acid, to then undergo esterification to ethyl acetate.

The temperature at which rums are aged will greatly affect the rate of maturation. It is reported that the rate of maturation at 25°C may double at 35°C (Kampen, 1975). This means that rums aged in the tropics will tend to mature more rapidly than those aged in temperate climates unless the warehouses are heated. The higher temperatures do, however, increase the annual rate of evaporation loss of rum through the wood.

The wood contact surface area may be increased by adding some charred or toasted oak chips to the barrels. The chips are relatively inexpensive as they can be made from scrap wood and can provide a means of standardizing the rate of maturation if fresh supplies are used each time.

Some rum producers add fruit extracts, sugar and even artificial rum essences to their products. The use of artificial essences should, however, be avoided or kept to a minimum as the product will usually have a noticeably artificial character. This is because an essence containing possibly four or five chemical compounds cannot give the overall 'roundness' of odor and taste that comes from the dozens or even hundreds of different congeners present naturally in a good heavy rum.

Characteristics of the aged rums should be carefully checked prior to bottling. Some blending may be required to ensure consistency with rum bottled previously under the same brand labels. Caramel coloring may be added to adjust the color of the rum to a standard in order to compensate for color variations acquired from the barrels used in aging.

Disposal of rum distillery wastes

The disposal of molasses stillage is a major problem in most rum producing areas as the liquid waste has a high biological oxygen demand (BOD) and will cause serious pollution if discharged into rivers or other watercourses.

There are some limited uses of the stillage. It may, for example, be sprayed on unpaved roads in dry seasons to reduce dust. Similarly, if evaporated to a syrup referred to as 'condensed molasses solubles', it may be used as a dust suppressant and source of minerals in cattle feeds. In some countries, a dried molasses stillage powder is sold for cattle feeding.

Evaporated stillage syrup may be burned in boilers as a partial replacement for bunker-C fuel oil; but the energy yield barely covers the energy required for the evaporation. There have also been reports of the use of molasses stillage as a binder in the production of concrete blocks. Generally, however, molasses stillage must be subjected to waste treatment processes. It was reported by Szendrey (1983) that the Bacardi Corporation in Puerto Rico uses an anaerobic digestion system to treat stillage and to produce methane for use as a boiler fuel. Other stillage waste treatment systems include anaerobic and aerobic lagoons.

References

- Arroyo, R. 1941. The manufacture of rum. *Sugar* 36(12).
- Arroyo, R. 1942. The manufacture of rum. *Sugar* 37(1), (5), (7).
- Arroyo, R. 1945. US Patent 2,386,924. Production of heavy rums.
- Arroyo, R. 1945. The production of heavy bodied rum. *International Sugar Journal* 40(11):34-39.
- Arroyo, R. 1945. Studies on rum. *Research Bulletin No. 5* (University of Puerto Rico, Agricultural Experiment Station, Rio Piedras, Puerto Rico), December.

- Arroyo, R. 1947. The economics of rum production. *International Sugar Journal* 49:292-294.
- Arroyo, R. 1947. The economics of rum production. *International Sugar Journal* 49:325-327.
- Arroyo, R. 1948a. The production of straight light rums from blackstrap. *International Sugar Journal* 50:150-152.
- Arroyo, R. 1948b. The flavour of rum - recent chromatographic research. *International Sugar Journal* 50:210.
- Arroyo, R. 1948c. Simultaneous production of light and heavy rum. *International Sugar Journal* 50:289-291.
- Arroyo, R. 1949a. The Arroyo fermentation process for alcohol and light rum from molasses. *Sugar Journal* 11(8):5-12.
- Arroyo, R. 1949b. A new rum distillation process. *Sugar* 44 (7):34-36.
- Arroyo, R. 1949c. Rum distillery yields and efficiencies-factors affecting them. *International Sugar Journal* 51:163-169, 189-191.
- Arroyo, R. 1950. Advanced features in rum fermentation. *International Sugar Journal* 52:42-44.
- Bureau of Alcohol Tobacco and Firearms. 1982. Regulations under the Federal Alcohol Administration Act. Washington, D.C.
- Clutton, D.W. 1974. Rum. *The Flavour Industry*, November/December pages 286-288.
- Ianson, P. 1971. Rum Manufacture. *Process Biochemistry*, July, pages 35-39.
- Kampen, W.H. 1975. Technology of the rum industry. *Sugar & Azucar* 70(8):36-43.
- Lehtonen, M. and M. Suomalainen. 1977. Rum. In: *Alcoholic beverages* (A.M. Rose, ed). Academic Press, London. pages 595-635.
- Paturau, J.M. 1969. By-products of the cane sugar industry. Elsevier, Amsterdam.
- Szendrey, L.M. 1983. The Bacardi Corporation digestion process for stabilizing rum distillery wastes and producing methane. In: *Energy from Biomass & Wastes VII Symposium*, Lake Buena Vista, Florida, Institute of Gas Technology, Chicago, Il. pages 767-794.

